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GB 1459646
GB 1381897
GB 1353871
GB 1284786
US 4284276
US 3819190
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(71) Applicant
Daniel Andrew Nepela,
106 Cedarcrest Place,
Los Gatos,
California 95020,
United States of America

(72) Inventor
Daniel Andrew Nepela

(74) Agents
Reddie and Grose,
16 Theobalds Road,
London,
WC1X 8PL

(54) Golf balls

(57) A golf ball is provided with dimples some at least of which have a depression or depressions around the periphery of the base of the dimple. The dimples are shallow but have objectively definable values in terms of a relationship determined by total volume and the volume of a normalizing cone within the dimple. The resultant aerodynamic properties provide longer flight distance for a given impact, apparently by improving the relationship of lift to drag. The ball preferably has 250 to 500 surface dimples of a total volume of 400 to 700 mm³, the product

$$V_T \times \frac{\Delta}{R}$$

being 750 mm³±100 mm³ wherein V_T is the total dimple volume, Δ is $V_D - V_C$, R is

$$\frac{V_C}{V_D},$$

V_D is the volume of an individual dimple and V_C is the internal volume of a diverging volume whose focal point is at the bottom center of the dimple and whose divergent end coincides in outline with the rim of the dimple.

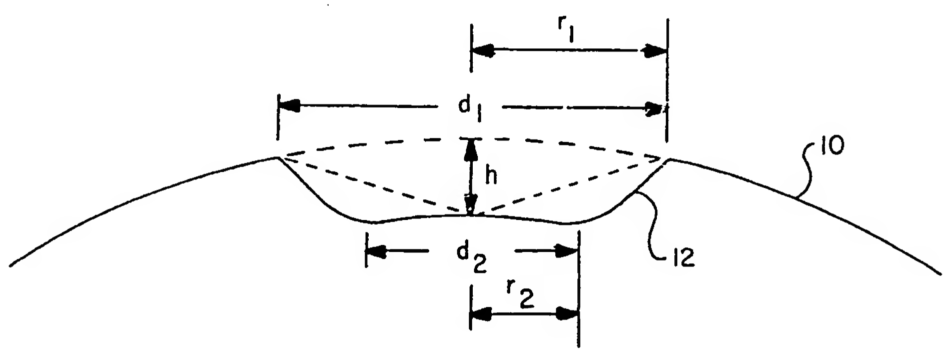

FIG.2

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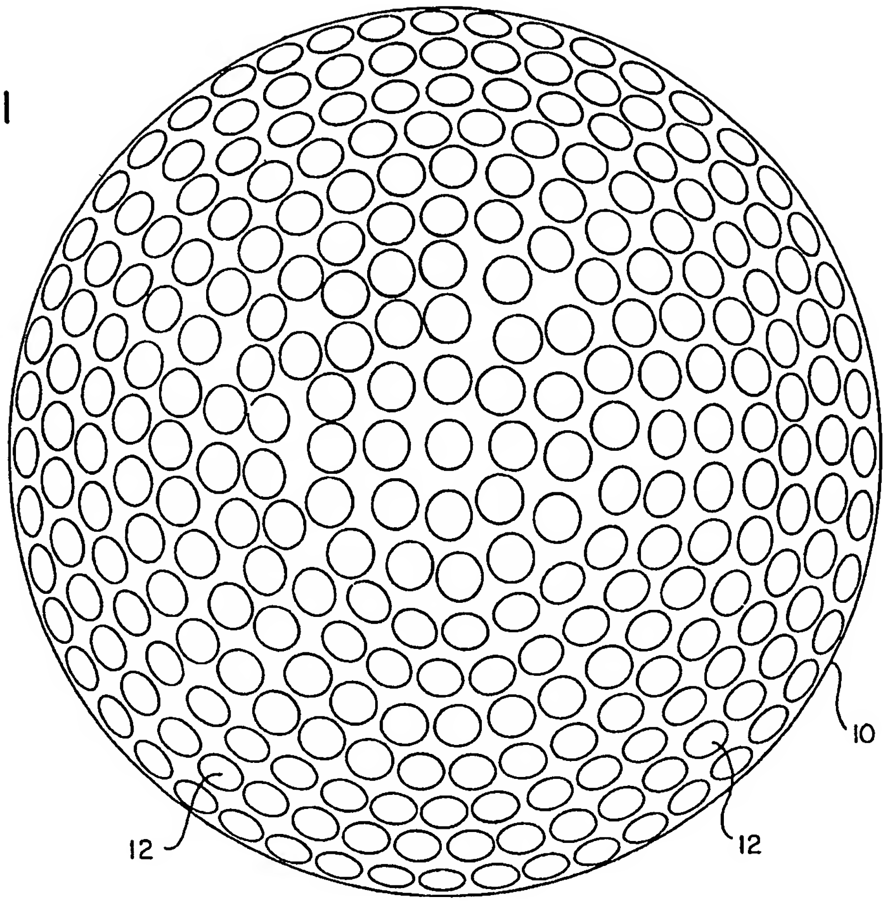
FIG. 1



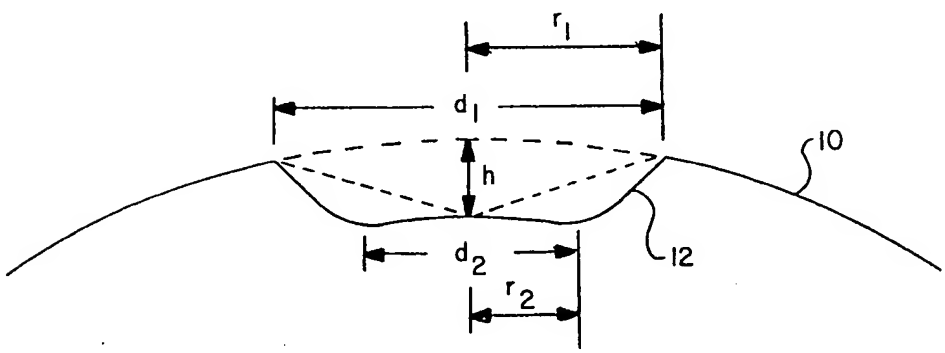
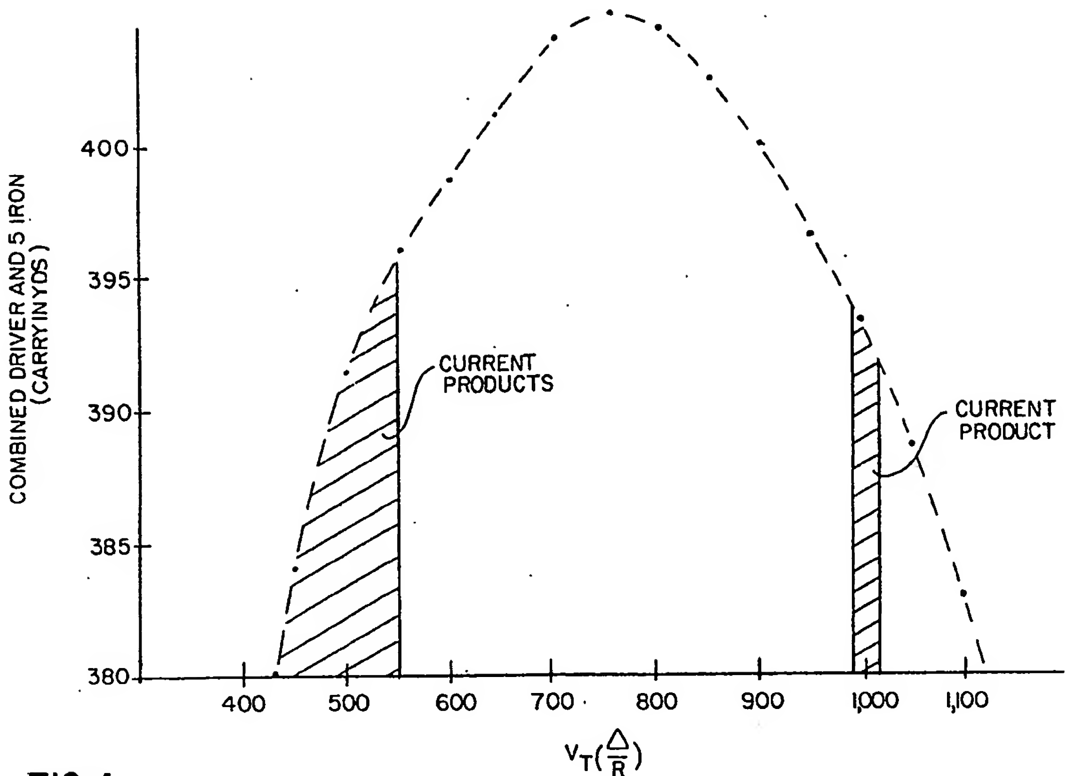


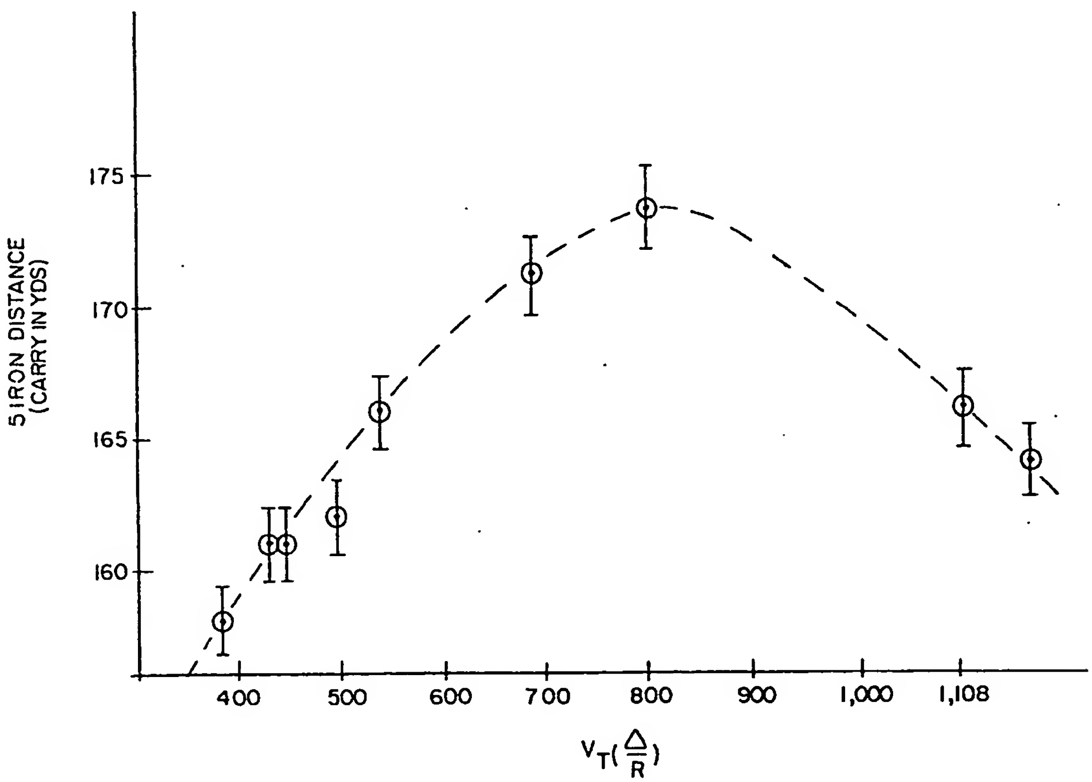
FIG. 2

FIG.3



COMBINED DRIVER AND 5 IRON (CARRY IN YDS)
400
395
390
385
380
CURRENT PRODUCTS
CURRENT PRODUCT
400
500
600
700
800
900
1,000
1,100
$V_T(\frac{\Delta}{R})$

FIG.4



5 IRON DISTANCE (CARRY IN YDS)
175
170
165
160
400
500
600
700
800
900
1,000
1,108
$V_T(\frac{\Delta}{R})$

FIG. 5

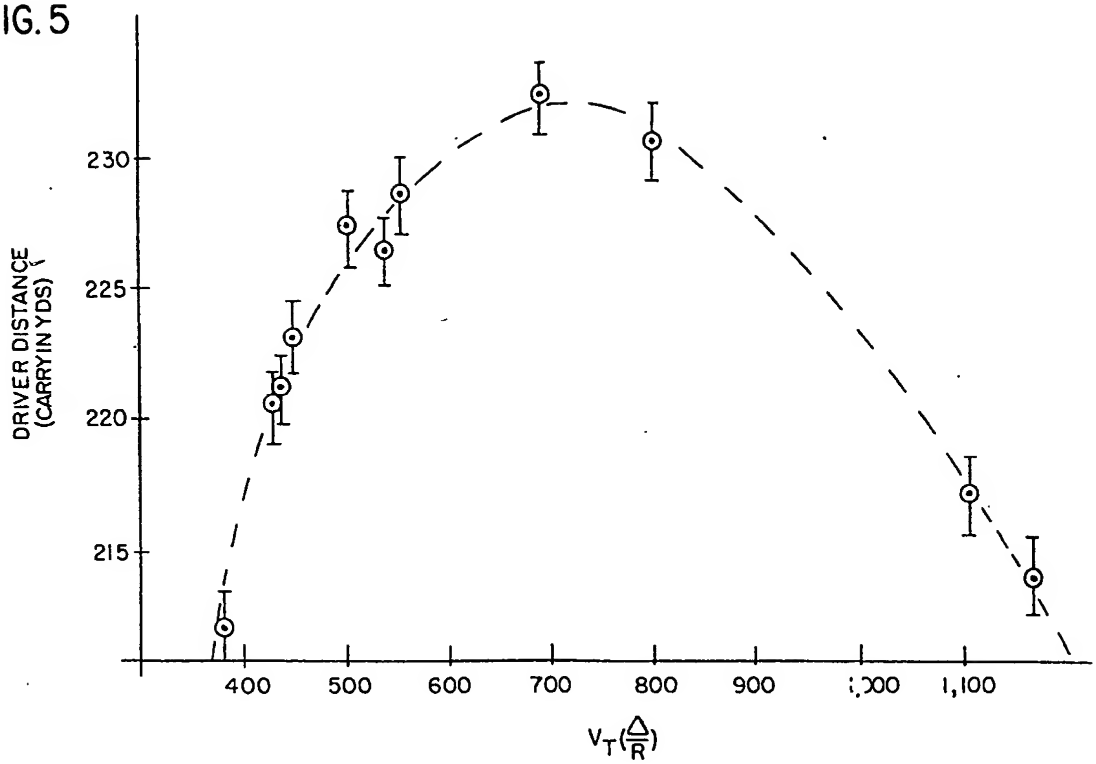
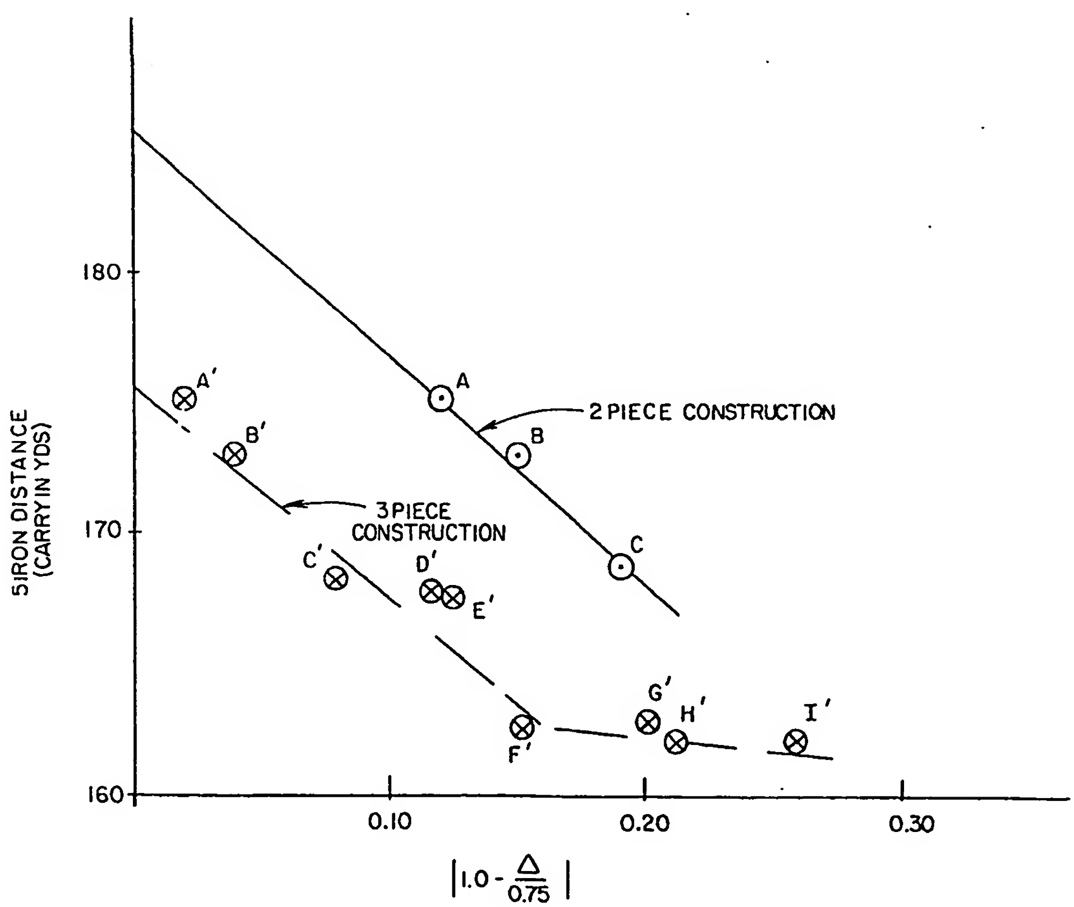

DRIVER DISTANCE (CARRY IN YDS)
230
225
220
215
400
500
600
700
800
900
1,000
1,100
$V_T(\frac{\Delta}{R})$

FIG.6


5 IRON DISTANCE (CARRY IN YDS)
180
170
160
0.10
0.20
0.30
$\left|1.0 - \frac{\Delta}{0.75}\right|$
A
B
C
2 PIECE CONSTRUCTION
A'
B'
C'
D'
E'
F'
G'
H'
I'
3 PIECE CONSTRUCTION

SPECIFICATION

Golf ball

Numerous attempts have been made, within the confines of tradition and governing rules and regulations, to improve the flight distance of golf balls in response to a given impact velocity and momentum. Most efforts have centered on the internal construction and structural makeup of the ball, because of the advances made possible by the constant improvement of materials. This approach has encountered somewhat arbitrarily set limitations, however, because the governing bodies of the sport have legislated against balls which have rebound capabilities in excess of established maximums. Thus, for given compression and compliance, aerodynamic factors and inertial considerations control.

Prior efforts at improving the characteristics of golf balls by modifying the aerodynamic properties led long ago to the introduction of distributed concavities or dimples, to improve flight stability. There has subsequently been considerable work on various surface geometries, as evidenced by the patents to Martin et al, No. 4,090,716, Melvin et al, No. 4,141,559 and Shaw et al, No. 4,142,727. Some of these techniques are based upon varying the areal distributions of dimples or the sizes of the dimples, largely to improve stability. The general tendency has been to use shallow dimples, and more of them, although one ball has been offered that uses extremely large and deep dimples. These variations, and specialized adaptations of other kinds, are employed for specific purposes, such as improved flight stability, better wear and cut resistance, and ease of molding. The patent and other literature does not discuss in depth, as far as is known, the interrelation between the various aspects of surface geometry and the consequent effects on flight distance.

Most golf ball surface geometries have apparently been devised empirically with particular objectives in mind, perhaps because a more general analysis is extremely complex. The impacted golf ball varies in initial translational velocity and rotational velocity dependent upon the club that is used. Both of these velocities, along with surface geometry, affect the aerodynamic lift and drag. Both velocities decrease during flight and their relationship as well as their magnitude determine lift and drag at any instant. Furthermore, the rotational inertia (and consequently the change in angular velocity) varies with the type of ball that is used, the currently popular two- and three-piece balls having substantial differences in this regard. One also must recognize that optimizing flight distance for one club only is not the objective because one is acually concerned in practical situations with composite tee-to-green distance for two or more clubs. Because the driver imparts a lower rotational velocity than a higher lofted club, the aerodynamic response of the golf ball is markely unlike under these two different conditions. The relatively lower rotational velocity of the ball hit with the driver means that it is less influenced by aerodynamic factors. Obtaining the best summation of results under typical conditions of multiple club use therefore demands considerable subtlety in arriving at a new aerodynamic surface geometry.

Golf balls in accordance with the invention are configured such that the total number of concavities, the total surface concavity volume, and the shape of the individual concavities are kept within objectively determinable limits. Using 250 to 500 concavities having a total volume of 400—700 mm³, the individual concavities are characterized by arcuate or angled rim depressions adjacent the periphery that increase the individual volume while maintaining a shallow concavity. The individual volumes are normalized so as to be maintained within selected limits by comparison to a reference cone volume dependent on the depth and peripheral dimensions of the concavity. It is found that when the total volume V_T is modified by multiplying with a normalizing factor, the resultant value should be in the range of 700—800 mm³. Tests show that in consequence the lift-to-drag ratio is enhanced without a concomitant increase in drag. Improvement exists both with the driver and more lofted clubs, although a balance is obtained such that the composite tee-to-green distance is optimally advanced.

Further in accordance with the invention, the normalizing reference for the concavity configuration is defined with respect to an interior cone or other diverging volume having its focus at the center bottom of the concavity, and its outer rim coincident with the peripihery of the concavity. Considering the volume of this reference cone as V_C, the volume of the dimple as V_D, the difference Δ is $V_D - V_C$, and the ratio R is

$$\frac{V_D}{V_C}.$$

Superior results are obtained when the product

$$V_T \frac{\Delta}{R}$$

is 750 mm³±100 mm³, the two- and three-piece balls occupying different positions within this range. The value of Δ alone can be used as a simplified reference, other conditions being as stated. For example, Δ of 0.75 mm³ represents a nominal optimum for the 5 iron. The improved concavity shape may be viewed as a shallow dimple having a rim depression that increases the peripheral volume to the desired range. A variety of arcs and straight-line segments may be used in meeting these conditions for the rim depression.

A better understanding of the invention may be had by reference to the following description,

taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a view of a golf ball in accordance with the invention, the concavities not being to scale and the specific shape thereof not being evident;

Fig. 2 is an enlarged, side sectional, view of a segment of the golf ball of Fig. 1, showing the nature of the curvature of the concavity therein, and an internal reference in the form of a normalizing cone;

Fig. 3 is a graph of composite drive and midiron distance for different values of

$$V_T\left(\frac{\Delta}{R}\right);$$

Fig. 4 is a graph of midiron distance versus the value of

$$V_T\left(\frac{\Delta}{R}\right);$$

Fig. 5 is a graph of driver distance versus

$$V_T\left(\frac{\Delta}{R}\right);$$

and

Fig. 6 is a graph of midiron distance versus an absolute value in which Δ is the only variable.

A golf ball 10 in accordance with the invention is depicted in general form in Fig. 1, in which the particular shape of the concavities 12 cannot be seen, for which purpose reference must be made to Fig. 2. However, the golf ball 10 in this example has the widely used total of 336 concavities or dimples, although from 250—500 dimples may be used in accordance with the invention. Further, the total volume of the dimples 12 is in the range of 400—700 mm^3, although the chosen volume is preferably varied depending upon whether a two-piece or three-piece ball is employed. It is found that the two-piece ball has a lower rotational velocity, in the range of 45—50 revolutions per second, whereas the three-piece ball has in the range of 60 revolutions per second, when struck with a driver by a low handicap golfer (e.g. 3 handicap or less). It is preferred, therefore, in accordance with the invention, to employ a total dimple volume (V_T) of 500—600 mm^3 for the three-piece ball, and a slightly higher volume of 530—650 mm^3 for the two-piece ball.

The volume of an individual concavity 12 is hereafter termed V_D, and is selected with respect to a number of factors that influence the aerodynamic and inertial properties, including the depth of the concavity, its shape, and the total concavity volume. These factors are interrelated by an internal reference volume, called the interior cone volume V_C. This reference volume is the theoretical volume swept out by a divergent shape having its focus at bottom center of the concavity 12 and its divergent end margin coextensive with the periphery of the concavity 12. The cone will typically be circular in cross-section , but can be of a different curved shape or even polygonal in cross-section. Its internal volume is representative of both the depth and transverse dimension of the concavity. Thus, two other relations may be defined, as follows:

$$\Delta = V_D - V_C$$

$$R = \frac{V_C}{V_D}$$

With reference to Fig. 2, it can be seen that the depth, h, of a concavity (which inversely is also the cavity height as viewed from bottom center) and an outer periphery having a given radius, r_1, determine the reference volume, in accordance with

$$V_C = 1/3\pi h(r_1)^2$$

The total volume of an individual concavity or dimple, V_D, may be determined by measurement, calculation or approximation. For a truncated spherical dimple having a bottom radius r_2 in the plane of truncation, as seen in Fig. 3, the volume calculation is:

$$V_D = 1/6\pi h(3(r_1)^2 + 3(r_2)^2 + h^2)$$

In accordance with the invention it has been shown by a series of tests that differential volumes which fall within a particular range of relationships to the reference volume, and which also have an acceptable total volume, improve the net aerodynamic properties of the golf ball to an appreciable degree, giving greater composite tee-to-green distance. The actual total volume V_T is modified by a normalizing factor

$$\frac{\Delta}{R}.$$

The relationship to be observed is that for a three-piece golf ball to U.S. standards, what may be called the normalized concavity volume,

$$V_T\left(\frac{\Delta}{R}\right),$$

is to be within a particular range, as follows, for a driver and five iron combination:

$$V_T\left(\frac{\Delta}{R}\right) = 750\ \text{mm}^3 \pm 100\ \text{mm}^3$$

It is also found that distance maximization for a driver is achieved (three-piece ball) for $\cong$700 mm^3$\pm$50 mm^3, while for the five iron alone the value is $\cong$800 mm^3$\pm$50 mm^3. The base values for

a two-piece ball differ somewhat, inasmuch as there is a slightly lower rotational velocity and inertia and a slightly higher normalized concavity volume is to be utilized. Similarly if one is primarily concerned with lower rotation, then a larger normalized concavity volume is also utilized. However, even with these variations, a normalized concavity volume will be within the range stated above. Furthermore, primary concern must be with the composite response property to the use of different lofted clubs, the driver and five iron combination providing the best way in which to characterize the sequence of club usage.

Referring to Fig. 2, two examples of shallow concavities having peripheral rim depressions in accordance with the invention are as follows:

	Example 1	*Example 2*
V_D	1.546 mm³	1.608 mm³
V_C	0.835 mm³	0.838 mm³
Δ	0.711 mm³	0.77 mm³
R	0.54	0.52
r_1	1.84 mm	1.77 mm
r_2	0.879 mm	0.93 mm
No Dimples	336	336
V_T	519 mm³	540 mm³
h	0.237 mm	0.256 mm
$\frac{\Delta}{R}$	1.316	1.48
$V_T\frac{\Delta}{R}$	683 mm³	799 mm³

It is evident that these constructions place no unconventional demands either on manufacture or customer acceptance of the balls. It is important to note, however, that as pointed out below it is not merely the shape of the shallow concavity but total concavity volume and the total number of cavities that provide the desired overall result.

In contrast, prior art constructions have been outside the specified range for normalized concavity volume, either higher or lower. Referring to Fig. 3; most of the prior art ball geometries that are currently in use have an excessively low normalized concavity volume, although they do typically incorporate 322 to 336 dimples. Most constructions simply employ a spherical arc, although the "Wilson ProStaff", which is at the higher end of this low range, has a dimple which may be regarded as a truncated cone. A different approach, and the opposite extreme of normalized concavity volume, is provided by a "Royal" ball which has a lesser number of extremely large spherical dimples, giving it a normalized concavity volume in excess of 1000 mm³.

In accordance with the invention, however, a normalized concavity volume for the three-piece ball peaks in the range of 750 mm³, for the driver and five iron combination. Referring to Fig. 4, the peak is in the range of 800 mm³ for the normalized concavity volume for the five iron alone. Referring to Fig. 5, it is in the range of 710 mm³ for the driver alone. At the extreme ends of these ranges there is a levelling off of the flight distance response. The tests were conducted under standardized conditions and statistically analyzed, and the curves are understood to be accurate on this basis to ±15 yards. Any golfer will attest that the consequent improvement in response is of significant benefit.

The profound effects of this special shaping of concavity geometry on the aerodynamic properties appear to arise from a favorable effect on lift without a comparable increase in drag. While a mathematical solution may be feasible it is so complex as to be beyond immediate capability. While the interactions are not fully understood, it is believed that the benefits of the geometry in accordance with the invention are realized in the pre-apex and apex portions of the flight rather than in the initial part of the flight. The initial foward velocity of a ball of given construction will be the same for identical hits, regardless of the concavity pattern. Although initial rotational velocities will also be the same, the effects of lift and drag are different with concavity shape and total concavity volume. Drag immediately starts to slow down rotational velocity, but lift does not have a substantial effect until translational velocity has slowed somewhat. Rotational inertia, which is higher in the three-piece than the two-piece ball, also acts against the reduction of rotational velocity. Consequently, it appears that the marginal depression around the periphery of the concavity may increase lift without substantially increasing drag, or may both increase lift and lower drag. These conditions hold true, however, only where the other parameters, namely total dimple number and total concavity volume, are in the ranges stated. Both lift and drag change, of course, as the translational and rotational velocities slow down. However, the effect on the ball is apparent visually, as a ball hit with the lofted iron climbs and floats to the apex of its flight before beginning a precipitous downward descent. It is therefore in the midflight, pre-apex and apex portions of the flight that the greatest benefits are realized.

The normalizing factor

$$\frac{\Delta}{R}$$

should be greater than unity, and preferably should be equal to or greater than 1.1. This places further constraints on the size and shape of the concavities. Further, there can be shown to be a substantially direct relationship between the difference Δ and the carry distance, as seen in Fig. 6. Fig. 6 illustrates variations in carry distance for a golf ball hit with a five iron and demonstrates that maximum distance is achieved (three-piece ball) at a Δ value of 0.5 mm³. Test results for the two-piece constructin appear to indicate the same optimum, but not test point was taken in

the vicinity of $\Delta=0.75$ mm³ for the two-piece ball. Plotting carry distance against the expression

$$\left|1.0-\frac{\Delta}{0.75}\right|$$

provides a basis for depicting the manner in which carry distance falls off symmetrically for values of Δ that are higher and lower than 0.75 mm³ and also shows that the variations are substantially linear out to approximately ±0.20 from the base value of 0.75.

Within the parameters heretofore defined, concavity geometries can be arcuate curvatures, as shown in Fig. 2, or a sequence of conical shapes merging into the bottom of the concavity. Furthermore, the dimple need not have a circular periphery, but can be polygonal in shape.

Spherical dimples, and cylindrical dimples the bottom corners of which can be radiused, having a value of

$$\frac{h}{d_1}$$

equal to or greater than 0.12 also satisfy the requirements. Such dimples may for example be from 240 to 400 in total number.

Claims

1. A golf ball whose outer surface has multiple concavities some at least of which have a depression or depressions around the periphery of the concavity base.

2. A ball according to claim 1 whose normalized concavity volume,

$$V_T\left(\frac{\Delta}{R}\right)$$

is 750 mm³$\pm$100 mm³ wherein V_T=total concavity volume $\Delta=V_D-V_C$,

$$R=\frac{V_C}{V_D},$$

V_D=individual concavity volume, and V_C=the volume of an interior cone having its apex at the bottom center of a concavity and diverging to a periphery coincident with the concavity rim.

3. A ball according to claim 2 wherein

$$\frac{\Delta}{R}$$

is equal to or greater than 1.1

4. A ball according to claim 2 or 3 wherein the value of

$$\left|1.0-\frac{\Delta}{0.75}\right|$$

is less than 0.20, Δ being expressed in mm³.

5. A golf ball having 250 to 500 surface dimples of a total volume of 400 to 700 mm³, the product

$$V_T\times\frac{\Delta}{R}$$

being 750 mm³$\pm$100 mm³ wherein V_T is the total dimple volume, Δ is

$$V_D-V_C,\ R \text{ is } \frac{V_C}{V_D},$$

V_D is the volume of an individual dimple and V_C is the internal volume of a diverging volume whose focal point is at the bottom center of the dimple and whose divergent end coincides in outline with the rim of the dimple.

6. A golf ball having 240 to 400 surface dimples, each having a shallow maximum depth and a shape sweeping out a substantial volume adjacent the side of a right circular cylinder intercepting the periphery of the dimple.

7. A golf ball according to claim 6 wherein each dimple has a concave depression adjacent the periphery of its base.

8. A golf ball according to claim 6 or 7 wherein the dimples are spherical in shape and have a ratio

$$\frac{h}{d}$$

of greater than 0.12, where h is the depth of the dimple and d is the diameter of its rim.

9. A golf ball substantially as hereinbefore described with reference to Figs. 1 and 2 of the accompanying drawings.

10. A golf ball substantially as hereinbefore described in Example 1 or 2.

11. A golf ball according to claim 1 and/or 5 and substantially as hereinbefore described with reference to the accompanying drawings.

12. A golf ball construction having improved distance carrying capability in contrast to another ball having the same compression and physical characteristics comprising:

an outer wall geometry having multiple concavities each having a marginal depression substantially increasing the concavity volume without increasing the concavity depth.

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